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PLASMA INSTABILITIES IN THE EQUATORIAL F-REGION: NATURAL AND AR--ETC(U)

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Plasma Instabilities in the Equatorial F-Region: Natural and Artificial Mechanisms

Edward P. Szuszczewicz, Sidney L. Ossakow,
Gary W. Sjolander, Julian C. Holmes,
and David N. Walker

April 17, 1979

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Accumulating information regarding the equatorial F-region ionosphere has proven it to be a particularly important domain for the communications and ionospheric sciences as well as investigation of fundamental plasma processes that have counterparts in atmospheric releases and controlled laboratory experiments. This wide range of interest has in recent years brought considerable intensity into equatorial investigations with major technical, scientific, and engineering advances contributing to our current understanding and future plans for adaptive communication system design and ionospheric modification and control. → next page (Continued)

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Rapid advances require occasional synthesis in order to draw proper perspectives and establish an improved definition of near-term and longer range plans. This document bears that objective, particularly as it relates to radar, rocket, and satellite studies of the turbulent ionospheric plasma state, the theoretical and computational descriptions, and chemical releases for controlled ionospheric modifications. Emphasis is placed on important relationships involving spread F, naturally-occurring ionospheric bite-outs, and artificial ionospheric holes. Current understanding is reviewed, deficiencies identified, and future programs involving the Naval Research Laboratory are discussed.

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PLASMA INSTABILITIES IN THE EQUATORIAL F-REGION: NATURAL AND ARTIFICIAL MECHANISMS

1. INTRODUCTION

Accumulating information regarding the equatorial F-region ionosphere has proven it to be a particularly important domain for the communications and ionospheric sciences as well as investigations of fundamental plasma processes that have counterparts in atmospheric releases and controlled laboratory experiments. This wide range of interest has in recent years brought considerable intensity into equatorial investigations with major technical, scientific, and engineering advances contributing to our current understanding and future plans for adaptive communications system design and ionospheric modification and control.

Rapid advances require occasional synthesis in order to draw proper perspectives and establish an improved definition of near-term and longer range plans. This document bears that objective, particularly as it relates to radar, rocket and satellite studies of the turbulent ionospheric plasma state, the theoretical and computational descriptions, and chemical releases for controlled ionospheric modifications. Emphasis is placed on important relationships involving spread-F, naturally-occuring ionospheric bite-outs, and artificial ionospheric holes. Current understanding is reviewed, deficiencies identified, and future programs involving the Naval Research Laboratory are discussed.

2. CURRENT UNDERSTANDING

2.1 Natural Ionospheric Holes and Equatorial Spread F

2.1.1. Status of Experimental Results

Since the original discovery of equatorial spread F (ESF) by Booker and Wells [1938], considerable observational and theoretical advances have been made in understanding the associated phenomena. The advances have largely been a result of improved "in-situ" measurement techniques, expanded and detailed ground-based radar observations, and the development of computational techniques that describe candidate plasma instabilities that might be active in the equatorial ionosphere.

The increased activity in the study of the equatorial ionosphere has resulted in modifications in theoretical models as new and improved data have been made available. But as yet there is no completely satisfactory explanation for the cause, development, chemistry, and transport of irregularities in the equatorial ionosphere. Even the longstanding morphology of equatorial F-region irregularities has been scrutinized, raising questions of previously unrecognized longitudinal dependencies.

Manuscript submitted January 1, 1979.

The Jicamarca Observatory (76.87°W, 11.95°S; 1° dip) near Lima, Peru has provided the most extensive data base for the time and space development of ESF. Operating at 50 MHz, the observatory's radar shows reflections from 3 meter size ionospheric irregularities as a function of altitude and time. Figure 1 shows a typical RTI (Range-Time-Intensity) plot collected in the evening during spread-F conditions. The abscissa is time, increasing from early evening on the left to the early morning hours on the right. The figure is used here to summarize salient features of the radar observations that will be coupled to subsequent discussions on chemistry and transport. More detailed discussions on RTI data at Jicamarca are available in the works of Woodman and La Hoz [1976], Farley et al. [1970] and Calderon [1975].

The gray-scale shows intensity of radar energy reflected from 3 meter scale size irregularities...the darker the image, the greater the reflected energy. The dotted line on the RTI plot locates the nominal altitute of the F-layer peak (h(max)). The h(max) line is not the result of actual data collected simultaneously with the RTI plot but represents accumulated information on the post-sunset behavior of the laminar ionosphere over Jicamarca (e.g., Farley et al. [1967], and Calderon [1975]).

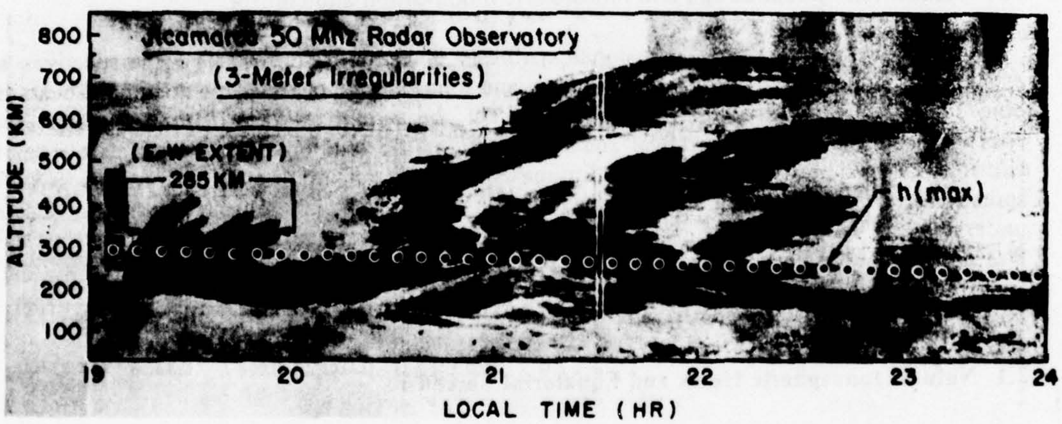


Fig. 1 — Range-time-intensity (RTI) plot of backscatter energy at Jicamarca Observatory. Superimposed is the nominal location of the F-layer peak (from *Szuszczewicz*, 1977).

The salient features in Figure 1 are as follows:

(a) Three-meter size irregularities are fundamentally a bottom-side spread-F condition in the early evening hours.

(b) The irregularities tend to rise-up and break-away from their lower altitude source region. This observation has spawned the use of the terms "bubbles," "plumes," and "fingers" to describe the motion of the irregularity domains.

(c) The irregularities that break-away generally move upward, with their intensity decreasing as time moves into the early morning hours.

(d) Bottom-side irregularities generally persist throughout the entire period of spread-F conditions. This is not the case for top-side irregularities.

Additional conclusions can be drawn from Woodman and La Hoz [1976] concerning the relationship between the time axis of the RTI plot and the east-west profile of irregularity structure. They note that since the ionospheric plasma superrotates in an easterly direction at an approximate rate of 125 m/sec, a one hour excursion in time on an RTI plot is equivalent to a 450 km E-W separation. With some qualifications imposed by temporal F-region developments, one can view one-hour segments of any RTI plot as an approximate E-W snapshot of regions of 3 meter size irregularities as one looks toward the south. This observation suggests the following conclusions:

(i) The three-meter size irregularities generated on the bottom-side tend to move upward and westward;

(ii) The east-west extent of the topside irregularity regions are extremely variable with time and altitude. Consider in Fig. 1 the early evening horizontal cut at an altitude of 340 km. A properly instrumented satellite or Spacelab payload passing through this region would observe three meter size irregularities over a 285 km range with substructure down to approximately 10 km.

A synthesis of radar results with the findings of rocket-, satellite-, and ionosonde investigations [Basu et al., 1976; Balsley et al., 1972; Dyson et al., 1974; Hanson et al., 1973; Farley, 1974; Kelley and Mozer, 1976; McClure and Woodman, 1972; McClure and Hanson, 1973] (including scintillation observations by Aarons and Allen [1971] and Koster [1972]) shows that equatorial F-region irregularities have latitudinal, diurnal, seasonal, and solar cycle variations with day-to-day perturbations superimposed. Spread F is essentially a nighttime phenomenon in the equatorial region ($\pm 20°$ of the magnetic dip equator) with the most intense periods of irregularities occurring within 2200 $\pm$ 3 hours LT. It appeared at first that the majority of irregularities fell into the "noiselike" structure where the amplitude increased approximately as the irregularity scale size from 70 m to 7 km (Dyson et al., 1974). More recently, however, the works of Brinton et al. [1975], McClure et al. [1977], Morse et al. [1977], and Szuszczewicz [1978] indicate that the bite-outs (or holes as they are often referred to) reported by Hanson and Sanatani [1973] and McClure and Hanson [1973] occur more frequently than was originally thought and in fact are considered just as characteristic of spread F as the less intense irregularities.

Typically, the ion composition is vastly different inside and outside the bite-outs. Fe^+ ions may be enhanced or depleted, with molecular ions usually more abundant inside the bite-out. Brinton et al. [1975] and McCLure et al. [1977] have found O^+ depleted by as much as a factor of 10^3 to a concentration below that of NO^+. The molecular ion NO^+ was found to be the dominant ion in the O^+ depleted region, and it was found that the bite-outs varied from a few kilometers to tens of kilometers in width. A typical satellite observation of equatorial bite-outs is shown in Fig. 2.

In the analysis of the data in Fig. 2 [Szuszczewicz, 1978] particular attention was given to possible relationships between ionospheric holes and the smaller-scale (3 m) irregularities observed by the Jicamarca radar. Ion chemistry and transport considerations were found to support the concept that equatorial holes and equatorial spread F could be one and the same phenomenon, with the smaller-scale irregularities imbedded within the much larger scale ionospheric depletions. The chemistry and transport model which emerged from the analysis considered a given chemical volume on the bottomside F layer ($[NO^+]$, $[O_2^+] > [O^+]$) to move upward through a stationary neutral atmosphere and appear at higher altitudes as a bite-out in

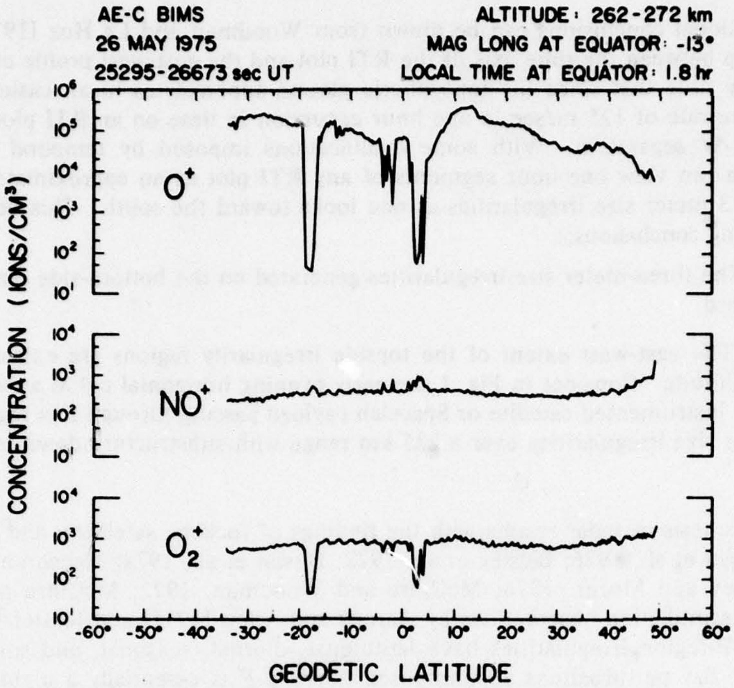


Fig. 2 — AE-C Bennett ion mass spectrometer (BIMS) measurements of O^+, O_2^+, and NO^+ in a single equatorial crossing near 265 km (from *Szuszczewicz*, 1978).

the local plasma density. As this plasma cell moved upward, the relative magnitudes of its ionic components depended on altitude through the height distribution of the neutral gases.

The concept of an upward moving ionospheric plasma cell is in agreement with the drift velocity measurements of McClure et al. [1977]. The concept is also consistent with the computational work of Scannapieco and Ossakow [1976], which showed that bottomside F region irregularities at low plasma densities ($10^2 - 10^4$ cm^{-3}) could be transported to more dense ionospheric domains ($10^5 - 10^6$ cm^{-3}) and appear as ionospheric holes. The source region can be low enough in the ionosphere to encompass domains of molecular ion domination but cannot be so low as to damp the growth of plasma instabilities necessary to raise it to higher altitudes.

The arguments developed by Szuszczewicz [1978], showing a parallel between large-scale ionospheric bite-outs and 3-m size irregularities normally identified with ionospheric spread F, are consistent with earlier observations of Fe^+ at high equatorial altitudes. But the present picture is broader in scope, indicating that NO^+ and O_2^+ in the holes are more likely to be consistent signatures of spread F since they are characteristic of bottomside composition which is maintained in first order as it is transported to the topside. The existence of Fe^+ on the topside is likely to be dependent on a two-step process which first requires the transport of metallic ions from the 95-km region to the bottomside of the F layer as a result of the strong polarization fields which accompany the equatorial electrojet. The continued upward movement of Fe^+ can then be a manifestation of the "fountain effect" as described by Hanson et al. [1972] or a further demonstration of a "frozen" chemical volume of bottomside composition transported to

higher altitudes by the Rayleigh-Taylor process [Dungey, 1956; Haerendel, 1974; Hudson and Kennel, 1975; Scannapieco and Ossakow, 1976]. In this case, O^+ will always be depleted, while the moleculars NO^+ and O_2^+ dominate; Fe^+ will be present only when the E region transport mechanism is actively depositing Fe^+ on the bottomside of the F layer.

2.1.2. Developments in Plasma Instability Analyses

The advances in the observational data have been paralleled by developments in theoretical and numerical simulation techniques. The result has been a relatively intensive probe into the fundamental plasma instability mechanisms causing ESF.

Serious ESF plasma analysis had its beginning in linear theories with Dungey [1956] being the first to suggest that ESF was initiated on the bottomside of the F-layer by the Rayleigh-Taylor instability. In 1957 Dagg proposed that ESF was due to coupling between the E and F regions. Two years later, Martyn [1959] suggested the $E \times B$ gradient drift instability and in 1963 Calvert proposed the downward motion of the neutral atmosphere at night as being responsible for ESF. (This mechanism was essentially equivalent to the $E \times B$ instability because of the relative motion between ions and neutrals in determining the instability). All of the linear instability mechanisms suffered from a common problem, the inability to explain the formation of irregularities at and above the F-layer peak.

The collisional Rayleigh-Taylor instability with field line averaging was also proposed (Balsley et al., 1972; Haerendel, 1974) as a linear instability mechanism. By averaging (integrating) the density along the magnetic field the total electron content profile becomes steeper on the bottomside and its effective peak is raised in altitute with respect to the local electron density peak. This allowed the linear mechanism to operate to slightly higher altitudes (~ 100 km greater), but still would not explain the existence of irregularities above this "new peak."

Hudson and Kennel [1975] pointed out the importance of the collisional drift mode in ESF in the wavelength regime 30m-100m. This mode could be excited on both the top and bottomside but still would not explain the longer wavelengths. In their paper, finite Larmor radius (FLR) corrections were also applied to the collisionless and collisional Rayleigh-Taylor instability.

Several nonlinear theories have been invoked to explain the different ESF observations. For example Hudson et al. [1973] suggested that the very smallest scale ($\lesssim$ 10m) irregularities (e.g., those seen by radar coherent backscatter) were due to a two step process. In this prescription a longer wavelength instability sets up the driving conditions for the shorter wavelengths to become unstable. This is similar in spirit to the successful two step theory (Sudan et al., 1973) proposed for Type II equatorial E region electrojet irregularities. Haerendel [1974] suggested that the range of wavelengths (many kilometers down to meters) exhibited by ESF phenomena was due to a multi-step process involving: (i) the collisional Rayleigh-Taylor (R-T) instability driven by gravity and the zero order electron density gradient scale length on the bottomside; (ii) the $E \times B$ gradient drift instability with vertical wave vectors then arises due to the horizontal large amplitude variations set up by the collisional R-T instability; (iii) the inertial (collisionless) dominated R-T instability then takes over, and finally (iv) kinetic drift waves grow upon these irregularities after they reach large amplitude. Chaturvedi and Kaw [1976] also pointed to the unlikely probability that the same instability mechanism could directly excite plasma irregularities over as wide a range of wavelengths as

that observed in ESF. They suggested a two step theory in which longer wavelength R-T modes coupled to kinetic collisional drift waves in a manner that resulted in a k^{-2} irregularity spectrum. (The need for the coupling of various instability processes has proven to be a necessary feature in explaining the full spectrum of ESF phenomena. As another illustration there is the very recent radar observation of 1 meter and 36 cm irregularities which motivated a proposed linear theory for high frequency drift waves generated by the drift-cyclotron and lower hybrid instabilities (Huba et al., 1978). This theory was set forth as a possible explanation for the occurrence of these irregularities below the ion gyroradius).

A major breakthrough was made by Scannapieco and Ossakow [1976] who performed a nonlinear numerical simulation of the collisional R-T instability for ESF geometry. The simulation results showed that the collisional R-T instability generated irregularities and bubbles (plasma density depletions) on the bottomside of the F region which subsequently rose beyond the F peak by nonlinear polarization-induced $E \times B$ forces. This was the first theoretical result to explain how long wavelength irregularities could apear on both the bottomside and topside of the F-region. The results were in accord with the observations of Kelley et al. [1976], McClure et al. [1977], Woodman and La Hoz [1976] and consistent with the more recent analysis of Szuszczewicz [1978]. Ossakow et al. [1979] extended the earlier work on nonlinear ESF to study the dependence on altitude of the F peak and the bottomside electron density scale length. They found that under favorable conditions, e.g. high altitude of the F peak and/or steep bottomside background electron density gradients, the collisional Rayleigh-Taylor instability caused linear growth on the bottomside of the F region. This in turn caused plasma density depletions or bubbles to be formed on the bottomside which then steepened on their top and rose nonlinearly above the F layer by polarization (induced) $E \times B$ motion. This in turn produced irregularities on the topside of the F layer where a linear analysis would predict no irregularities. High altitude of the F peak, small bottomside background electron density grandient scale lengths, and large initial bottomside percent depletions yielded large vertical bubble rise velocities. They specifically showed that changing the altitude of the F peak from 300 km to 430 km can have dramatic effects on the evolution of ESF. One of their simulations is shown in Fig. 3.

In parallel efforts Ossakow and his colleagues advanced an analytical nonlinear mode-mode coupling theory for the coherent development of the collisional R-T instability (Chaturvedi and Ossakow, 1977). Their theory suggested that vertical modes would be dominant and result in a k^{-2} power spectrum. Hudson [1978] extended the results to the collisionless R-T regime and reached similar conclusions. Analytical models for the rise of collisional and collisionless R-T ESF bubbles, in analogy with fluid bubbles, were presented by Ott [1978]. At the same time, Ossakow and Chaturvedi [1978] presented analytical models for the rise of collisional R-T ESF bubbles within the context of the electrical analogy with barium clouds.

Costa and Kelley [1978a,b] suggested that coherent steepened structures and not turbulences would give a k^{-2} power spectrum. Moreover, these sharp gradients could cause small scale sizes ($\sim$ 20m) by collisionless low frequency (much less than the ion gyrofrequency, Ω_i) kinetic drift waves via a two step process. Their analysis was a linear one carried out on a nonlinear state, i.e., one achieves the steepened gradients by nonlinear processes and then one performs linear theory on this state. Kelley and Ott [1978] suggested that the ESF bubbles, in the collisionless R-T regime, generate a wake with vortices. They then applied two dimensional fluid turbulence theory to the model. This resulted in the development of turbulence at shorter and longer wavelengths than the bubble size. This in turn led to a prediction of k^{-1} for the power spectrum (which does not appear to be in agreement with existing experimental observa-

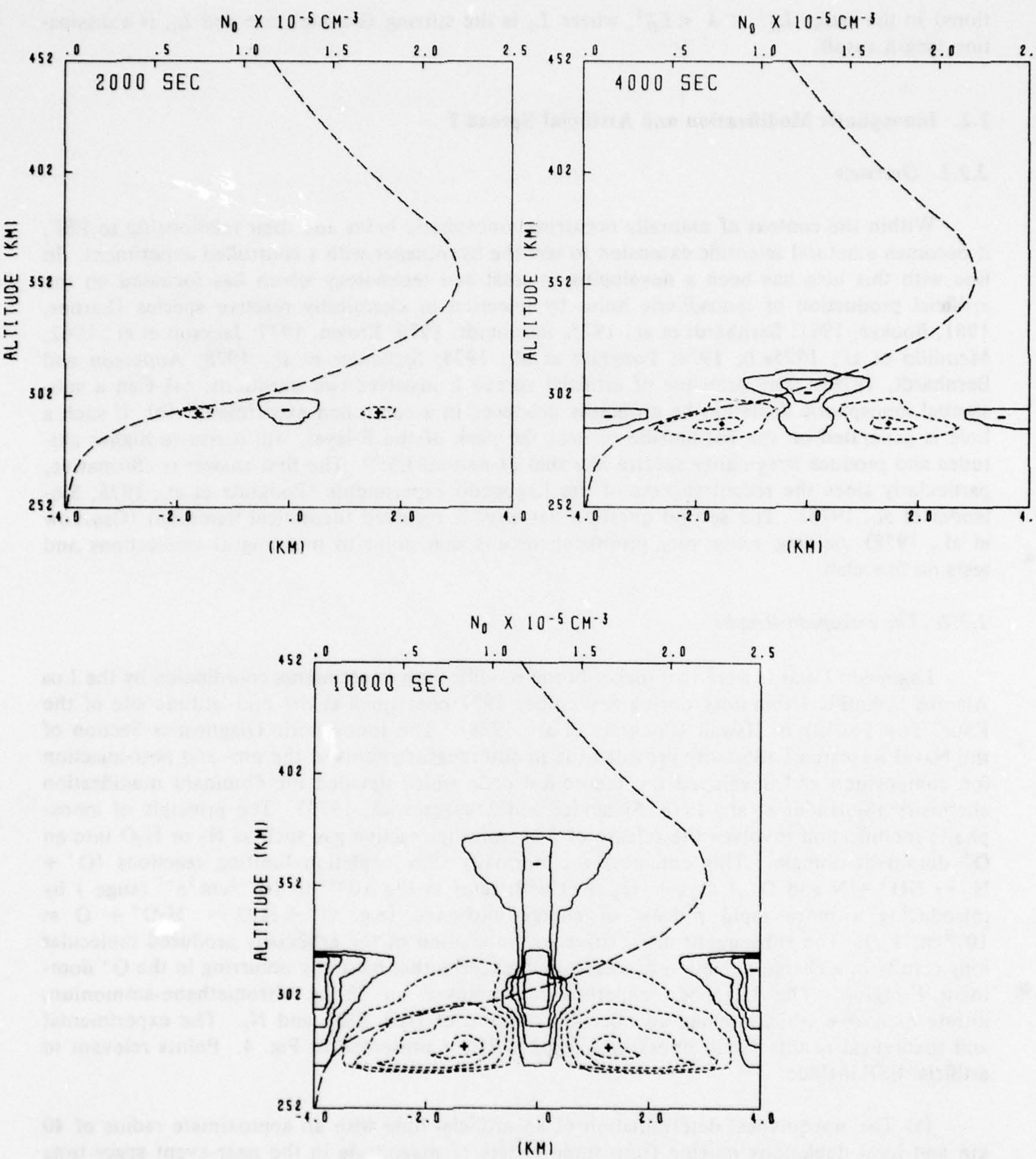


Fig. 3 — Contour plots of constant n_1/n_0 for the simulation ESF 1 at t = 2000, 4000, and 10,000 sec. The small dashed contours with a plus sign inside and the solid contours with a minus sign inside indicate enhancement and depletions over the ambient electron number density. The large dashed curve depicts the ambient electron number density (values on upper horizontal axis), n_0, as a function of altitude. The vertical y axis represents altitude, the lower horizontal x axis is east-west range, and the ambient magnetic field is along the z axis, out of the figure (from *Ossakow et al.* 1978).

tions) in the range $L_S^{-1} < k < L_D^{-1}$, where L_S is the stirring (bubble) size and L_D is a dissipation length cutoff.

2.2. Ionospheric Modification and Artificial Spread F

2.2.1. Overview

Within the context of naturally occurring ionospheric holes and their relationship to ESF, it becomes a natural scientific extension to test the hypotheses with a controlled experiment. In line with this idea has been a developing interest and technology which has focussed on the artificial production of ionospheric holes by injection of chemically reactive species (Barnes, 1961, Booker, 1961; Bernhardt et al., 1975; Bernhardt, 1976, Brown, 1977; Jackson et al., 1962; Mendillo et al., 1975a,b, 1978; Pongratz et al., 1978; Sjolander et al., 1978; Anderson and Bernhardt, 1978). The principle of artificial spread F involves two questions: (a) Can a substantial ionospheric depletion be artificially produced in a controlled experiment? (b) If such a hole is generated on the bottomside or near the peak of the F-layer, will it rise to higher altitudes and produce irregularity spectra like that of natural ESF? The first answer is affirmative, particularly since the recent success of the Lagopedo experiments (Pongratz et al., 1978; Sjolander et al., 1978). The second question has already received theoretical treatment (Ossakow et al., 1978) yielding some very promising results that point to meaningful applications and tests on Spacelab.

2.2.2. The Lagopedo Results

Lagopedo I and II were two rocket-borne modification experiments coordinated by the Los Alamos Scientific Laboratory during September 1977 operations at the mid-latitude site of the Kauai Test Facility in Hawaii (Pongratz et al., 1978). The Ionospheric Diagnostics Section of the Naval Research Laboratory provided the in situ measurements of the pre- and post-injection ion composition and developed the theoretical code which detailed the dominant modification chemistry (Sjolander et al., 1978, Sjolander and Szuszczewicz, 1979). The principle of ionospheric modification involves the release of a chemically reactive gas such as H_2 or H_2O into an O^+ dominant domain. This enhances the normally slow depletion limiting reactions ($O^+ + N_2 \rightarrow NO^+ + N$ and $O^+ + O_2 \rightarrow O_2^+ + O$ with rates in the 10^{-11} to $10^{-13} cm^3 s^{-1}$ range) by introducing a more rapid process of charge exchange (e.g. $O^+ + H_2O \rightarrow H_2O^+ + O$ at $10^{-9} cm^3 s^{-1}$). The subsequent dissociative recombination of the artificially produced molecular ions results in a charge-depletion process which exceeds that naturally occurring in the O^+ dominant F-region. The Lagopedo experiments employed an 88 kg nitromethane-ammonium nitrate explosive which yielded an injection mixture of H_2O, CO_2, and N_2. The experimental and theoretical results (solid lines) of Lagopedo II are presented in Fig. 4. Points relevant to artificial ESF include:

(a) The unequivocal determination of an artificial hole with an approximate radius of 40 km and local depletions ranging from three orders of magnitude in the near-event space-time domain to approximately a factor of 50% near the edges of the injected cloud of gases.

(b) The presence of ion components normally not found in the natural ionosphere (e.g. H_3O^+, H_2O^+, HCO^+, HCO_2^+; and Al^+ from disintegration of the explosive cannister). These were products of the injection process and in the application to artificial ESF could prove themselves as easily identified tracers (Szuszczewicz, 1978) if the hole were created on the bottomside and rose to higher altitudes.

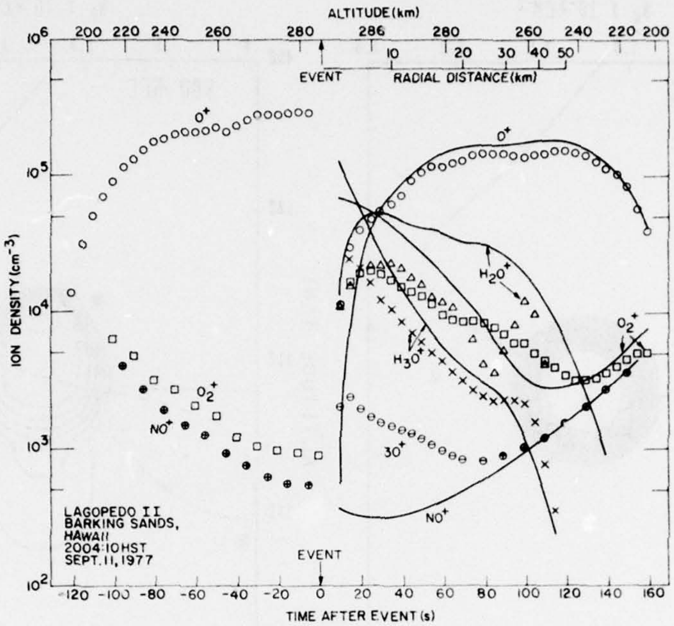
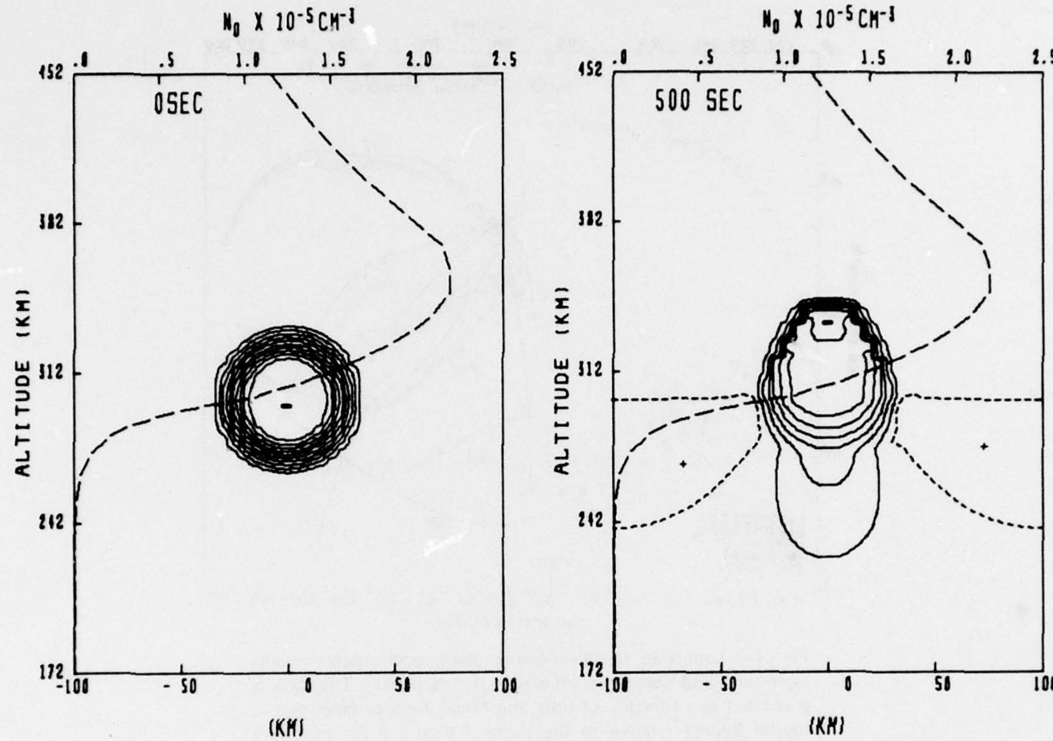


Fig. 4— Lagopedo II rocket-borne mass spectrometer results (symbols) and computer simulation (solid lines). The data is presented as a function of time and radial distance (see inset at top of figure) relative to the event (i.e. $t \equiv 0$ for explosive detonation). Rocket altitude is presented on the top abscissa (from *Sjolander and Szuszczewicz*, 1979).

2.2.3. *Artificial Equatorial Spread-F*

In order to explore the possibility of artificial ESF Ossakow et al. [1978] developed a simplified model which merged the principles of Lagopedo with previous nonlinear numerical codes. They did not follow the chemical kinetics of the actual time- and space-dependent depletion process, but followed the evolution of the hole after it was produced (assuming time-dependent chemistry was no longer in effect). One of the cases which they considered in their simulations assumed the F-layer at 350 km with a peak background plasma density $n_o = 2.2$ (10^5) cm^{-3}. Their initial conditions on the hole assumed a constant 97% depletion over a central 30 km domain decreasing to the ambient density over a 20 km extent on each side (total extent of the assumed hole was 70 km). The hole was located on the bottom-side gradient at a release altitude of 300 km. The evolution of the bubble and its penetration above the F-layer peak is shown in Fig. 5. At t = 2000 sec the top of the hole has penetrated the F-peak... exhibiting a more rapid rise time than in a natural spread-F hole (~ 8000 sec) in this same ionospheric density profile (see Fig. 3). This happens because, by definition, a large artificial depletion bypasses the initial linear phase of development.

These results and others in the same work point to the realistic application of chemical modification to artificial ESF.



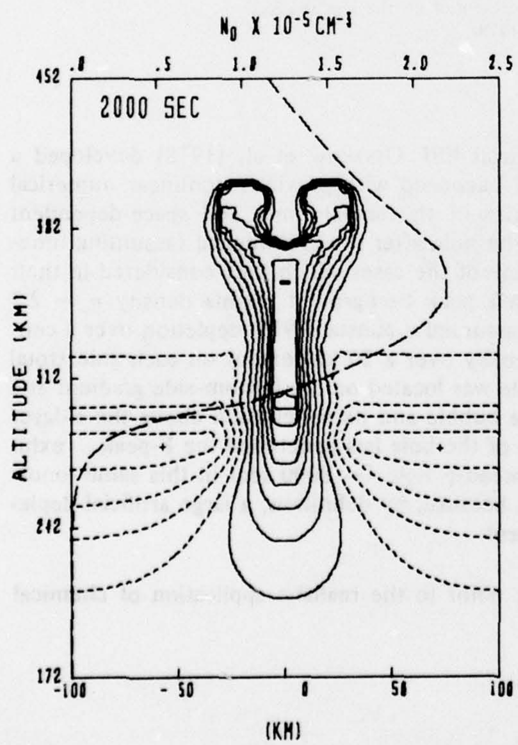


Fig. 5 — Contour plots of constant n_1/n_0 for t = 0, 500, and 2000 sec. The large dashed curve represents a plot of the ambient electron number density (values on upper horizontal axis), n_0, as a function of altitude. The vertical (y) axis represents altitude, the lower horizontal (x) axis east-west range, and the ambient magnetic field is out of the figure (z). At t = 0 sec (initial condition), the circular contours represent the artificial depletion (-) such that the outermost contour is a 16% depletion and the innermost is a 96% depletion (inside this contour is a constant 97% depletion). At t = 500 sec, the smaller dashed contours are contours of constant n_1/n_0 for plasma density enhancements (+). The enhancement contour represents a 19% enhancement. At t = 2000 sec, the inner enhancement contour represents a 236% enhancement (from *Ossakow et al.*, 1978a).

3. DEFICIENCIES AND THE NEED FOR FUTURE INVESTIGATIONS

3.1. Electron Density and Spectral Characteristics

Although much progress has been made in understanding ESF phenomena, more detailed work needs to be done on the fundamental plasma process in order to definitively unfold the active first principles and their coupling to the natural ionosphere. For example, we have yet to define the electron density fluctuation power spectrum over the broad domain encompassed by ESF. The preceding sections clearly point to the importance of these measurements as a first approach in understanding the multi-step plasma processes in which large scale irregularities (kilometers) cascade to much smaller dimensions (<3 meters). In this regard there has been only one satellite investigation which attempted (Dyson et al., 1974) to define the irregularity spectra and associated causal mechanisms. The data come from the OGO-6 retarding potential analyzer operating at altitudes above 460 km at an orbital inclination of 82°. With the instrument limited to scale sizes greater than 70 m, the most common feature at all latitudes appeared to be an irregularity spectrum with amplitude structure increasing approximately as the scale size. Departures from this power law spectral behavior were classified as "sinusoidal" or "ground glass" irregularities and tentatively identified as different phases of the (unknown) process responsible for the power law dependence. The work of Dyson et al. [1974], along with the cataloging efforts of McClure and Hanson [1973], represents one of the most important experimental steps. From here higher resolution correlative plasma measurements must be made in high and low inclination orbits in order to establish the degree of isotropy in the irregularity spectra perpendicular and parallel to the geomagnetic field. The definition of spectral characteristics needs to be extended down to sizes $\leq$ 3 meters and must be studied within the *context of positions relative to the F-layer peak and any superimposed ionospheric depletions.* These measurements must also be extended into the domain of time correlation in order to study the variations of spectral distributions that are expected to take place during the development of the multistep plasma instability processes.

3.2. Electron Temperature and Chemistry

The need for extended studies of electron density fluctuation power spectra cannot stand alone in determining all the causal mechanisms. The existing data shows that any study of equatorial irregularities must determine the degree of balance between the chemistry and the dynamics of the ionosphere. Here the electron energy plays a critical role in the dissociative and radiative recombination processes (Biondi, 1969, 1972; Lindinger et al., 1974; Oppenheimer et al., 1977; Torr et al., 1976; Oppenheimer and Brace, 1976). The impact of T_e on chemistry, coupled with the fact that T_e controls the short wavelength cutoff in the linear development of ionospheric fluid-type plasma instabilities (Ossakow, 1974) establishes the measurement of electron temperature as important to a full understanding of spread-F irregularities and equatorial bite-outs.

The T_e measurements must be made inside and outside of the ionospheric holes, as well as across the sharp boundaries that are a characteristic feature of many of the depleted domains. The measurement capability must clearly extend to rapidly changing density environments and into domains where contaminating species (e.g. H_2O in a modification experiment) can seriously degrade the measurement integrity (Holmes and Szuszczewicz, 1975; Szuszczewicz and Holmes, 1975). The electron temperature must be determined in F region chemical release experiments, particularly in the daytime ionosphere where the electron gas can be heated by as much as a factor of two in the presence of an artificially depleted ion population (Bernhardt,

1976). The T_e measurement should also be done simultaneously with the determination of electron density fluctuation power spectra in order to determine the role of electron energy in the naturally occurring instability processes as well as those that might be triggered by chemical releases.

3.3 Current and Projected Efforts Within NRL

In an effort to close the gap between macroscopic phenomenology and detailed understanding of causal mechanisms, the Naval Research Laboratory is participating in a number of programs specifically designed for the development of predictive capabilities for the naturally- and artifically-triggered onset of ESF. In many cases these programs involve cooperative efforts with other agencies. Near-term contributors in this category include the DNA/Kwajalein campaign planned for August 1979 and the F-region polar orbiting STP satellite S3-4.

The DNA effort involves two rockets instrumented with high resolution plasma probes, electric field sensors, a mass spectrometer, and a VHF-UHF beacon experiment. The rocket launches will be timed for penetration of ESF plumes and the diagnostics will be coupled with the ground-based measurements of radar, ionsonde, and neutral winds.

The STP/S3-4 satellite (launched March 1978) includes a pair of precision plasma probes which provide direct measurements of the ionospheric state, its condition of irregularitiy, and the associated electron density fluctuation power spectra. This experiment is providing the first satellite opportunity to assemble power-law information to wavelengths as small as 19 meters and to compare the results with the Kwajalein/Altair radar observations. In addition, the experiment has operational modes which test the roles of electron energy and ion composition in the distribution of wave energy in the cascading process of large-to-small scale ionospheric plasma irregularities.

Longer range plans are focussed on formation flights of LASSII (a Shuttle-launched free-flying satellite) with orbiter-borne sensor packages. The tandem operations will provide the first capability for the separation of space and time variations in the ionosphere and their effect on transionospheric communications. Initial efforts will involve ionospheric studies of localized chemical releases while full advantage will be taken of ground-based diagnostic systems as well as existing transit and geostationary satellites. LASSII is a multi-agency, multi-purpose mission designed for 1-3 week investigations with subsequent recovery by Shuttle. It will carry a state-of-the-art complement of instrumentation designed for basic and applied ionospheric plasma research and the associated development and test of DoD space communications networks. Current level of effort within the Space Test Program plans for operations of the Shuttle-borne complement in FY-82.

All these programs couple experimental and computational efforts which address specific issues involving fundamental causal mechanisms. Among these issues are:

(a) The relationship between very small scale irregularities ($\lesssim 3$ m) and the longer wavelength fluid type perturbations;

(b) The effects of zero-order ionospheric plasma conditions including location and intensity of the F-layer peak, the scale size of the bottomside gradient, and ion inertia;

(c) The ESF bubble decay process and the role of plasma diffusion perpendicular and parallel to the geomagnetic field;

(d) The transport of bottomside F region plasma cells to higher altitudes and the variations in initial characteristics (e.g. N_e, T_e, and M_i) as the cell penetrates the F-layer peak and appears on the topside;

(e) Irregularity spectral characteristics as a function of space, time (in the instability growth sequency), and F-layer parameters...particularly as they correlate in space relative to ambient depletions (i.e. What are the spectral indices within the hole, across its boundaries, and in the nearby domains?).

Programmatic details and associated results will appear in subsequent publications.

REFERENCES

Aarons, J., and R. S. Allen, "Scintillation boundary during quiet and disturbed magnetic conditions," *J. Geophys. Res.* **76**, 170, 1971.

Anderson, D. N., and P. A. Bernhardt, "Modeling the effects of an H_2 gas release on the equatorial ionosphere," *J. Geophys. Res.* **83**, 4777, 1978.

Balsley, B. B., G. Haerendel and R. A. Greenwald, "Equatorial Spread F: Recent observations and a new interpretation," *J. Geophys. Res.* **77**, 5625, 1972.

Barnes, Jr., C., Comment on Paper by Henry G. Booker, "A local reduction of F-region ionization due to missile transit," *J. Geophys. Res.* **66**, 2589, 1961.

Basu, S., S. Basu, and B. K. Khan, "Model of equatorial scintillations from in-situ measurements," *Radio Science*, **11**, 821, 1976.

Bernhardt, P. A., "Response of the ionosphere to the injection of chemically reactive vapors," Tech. Rpt. No. 17, Radio Science Laboratory, Stanford Electronics Laboratories, Stanford University (May 1976).

Bernhardt, P. A., C. G. Park, and P. M. Banks, "Depletion of the F_2 region ionosphere and the protonosphere by the release of molecular hydrogen," *Geophys. Res. Lett.* **2**, 341, 1975.

Biondi, M. A., "Charged particle recombination processes," in *Reaction Rate Handbook*, DNA 1948H, p. 16-1 edited by M.H. Bortner and T. Baurer (DASIAC, GE TEMPO, Santa Barbara, CA 1972).

Biondi, M. A., "Atmospheric electron-ion and ion-ion recombination processes," *Can. J. Chem.* **47**, 1711, 1969.

Booker, H. G., "A local reduction of F-region ionization due to missile transit," *J. Geophys. Res.* **66**, 1073, 1961.

Booker, B. B., and H. W. Wells, "Scattering of radio waves by the F-region of the ionosphere," *Terres. Magn.* **43**, 249, 1938.

Brinton, H. C., H. G. Mayr, and G. P. Newton, "Ion composition in the nighttime equatorial F-region: Implications for chemistry and dynamics," *Trans. Am. Geophys. U.* **56**, 1038, 1975.

Brown, N. B., H. C. Stenback-Nielsen, and R. D. Hunsucker, "Scarab — An F-region ionosphere modification experiment using water," (abstract), *EOS Trans. AGU.* **58**, 454, 1977.

Calderon, C. H. J., "Report on coordinated satellite and incoherent scatter observations," Rpt. of the Instituto Geofisico del Peru, Radio Observatorio de Jicamarea (October 1975).

Calvert, W., "Instability of the equatorial F layer after sunset," *J. Geophys. Res.* **68**, 2591, 1963.

Chaturvedi, P., and P. Kaw, "An interpretation for the power spectrum of Spread F irregularities," *J. Geophys. Res.* **81**, 3257, 1976.

Chaturvedi, P. K. and S. L. Ossakow, "Nonlinear theory of the collisional Rayleigh-Taylor instability in equatorial Spread F," *Geophys. Res. Letts.* **4**, 558, 1977.

Costa, E., and M. C. Kelley, "On the role of steepened structures and drift waves in equatorial Spread F," *J. Geophys. Res.* **83**, 4359, 1978a.

Costa, E., and M. C. Kelley, "Linear theory for the collisionless drift wave instability with wavelengths near the ion gyroradius," *J. Geophys. Res.* **83**, 4365, 1978.

Dagg, M., "The origin of the ionospheric irregularities responsible for radio-star scintillations and Spread F, 2, Turbulent motion in the dynamo region," *J. Atmos. Terres. Phys.* **11**, 139, 1957.

Dungey, J. W., "Convective diffusion in the equatorial F region," *J. Atmos. Terres. Phys.* **9**, 304, 1956.

Dyson, P. L., J. P. McClure and W. B. Hanson, "In situ measurements of the spectral characteristics of F-region ionospheric irregularities," *J. Geophys. Res.* **79**, 1497, 1974.

Farley, D. T., J. P. McClure, D. L. Sterling, and J. L. Green, "Temperature and compostion of the equatorial ionosphere," *J. Geophys. Res.* **72**, 5837, 1967.

Farley, D. T., B. B. Balsley, R. R. Woodman, and J. P. McClure, "Equatorial Spread F: Implications of VHF radar observations," *J. Geophys. Res.* **75**, 7199, 1970.

Farley, D. T., "Irregularities in the equatorial ionosphere: The Berkner Symposium," *Rev. Geophys. Space Phys.* **12**, 285, 1974.

Haerendel, G., "Theory of equatorial Spread F," preprint, Max-Planck Institute fur Physik und Astrophysik, Garching, West Germany, 1974.

Hanson, W. B., and S. Sanatani, "Large N_i gradients below the equatorial F-peak," *J. Geophys. Res.* **78**, 1167, 1973.

Hanson, W. B., D. L. Sterling, and R. F. Woodman, "Source and identification of heavy ions in the equatorial F layer," *J. Geophys. Res.* **77**, 5530, 1972.

Hanson, W. B., J. P. McClure, and D. L. Sterling, "On the cause of equatorial spread-F," *J. Geophys. Res.* **78**, 2353, 1973.

Holmes, J. C. and E. P. Szuszczewicz, "A versatile plasma probe," *Rev. Sci. Inst.* **46**, 592, 1975.

Huba, J. D., P. K. Chaturvedi, S. L. Ossakow, and D. M. Towle, "High frequency drift waves with wavelengths below the ion gyroradius in equatorial Spread F," *Geophys. Res. Letts.* **5**, 695, 1978.

Hudson, M. K., "Spread F bubbles: Nonlinear Rayleigh-Taylor mode in two dimensions," *J. Geophys. Res.* **83**, 3189, 1978.

Hudson, M. K., C. F. Kennel, and P. K. Kaw, "A two-step drift mode theory of equatorial Spread F," *Trans. Am Geophys. Un.* **54**, 1147, 1973.

Hudson, M. K., and C. F. Kennel, "Linear theory of equatorial Spread F," *J. Geophys. Res.* **80**, 4581, 1975.

Jackson, J. E., H. A. Whale, and S. J. Bauer, "Local ionospheric disturbance created by a burning rocket," *J. Geophys. Res.* **67**, 2059, 1962.

Kelley, M. C., G. Haerendel, H. Kappler, A. Valenzuela, B. B. Balsley, D. A. Carter, W. L. Ecklund, C. W. Carson, B. Hausler, and R. Torbert, "Evidence for a Rayleigh-Taylor type instability and upwelling of depleted density regions during equatorial Spread F," *Geophys. Res. Letts.* **3**, 448, 1976.

Kelley, M. C., and E. Ott, "Two-dimensional turbulence in equatorial Spread F," *J. Geophys. Res.* **83**, 4369, 1978.

Kelley, M. C., and F. S. Mozer, "A review of the recent results of in-situ ionospheric irregularity measurements and their relation to electrostatic instabilities," in *Effects of the Ionosphere on Space Systems and Communications*, J. M. Goodman ed., (Gov't. Printing Office, Wash., D.C.), 1976.

Koster, J. R., "Equatorial scintillation," *Planet. Space Sci.* **20**, 1999, 1972.

Lindinger, W., F. C. Fehsenfeld, A. L. Schmeltekopf, and E. E. Ferguson, "Temperature dependence of some ionospheric ion-neutral reactions from 300° - 900°K," *J. Geophys. Res.* **79**, 4753, 1974.

Martyn, D. F., "Large-scale movements of ionization in the ionosphere," *J. Geophys. Res.* **64**, 2178, 1959.

McClure, J. P., W. B. Hanson, and J. H. Hoffman, "Plasma bubbles and irregularities in the equatorial ionosphere," *J. Geophys. Res.* **82**, 2650, 1977.

McClure, J. P., and R. F. Woodman, "Radar observations of equatorial spread F in a region of electrostatic turbulence," *J. Geopys. Res.* **77**, 5617, 1972.

McClure, J. P., and W. B. Hanson, "A catalog of ionospheric F region irregularity behavior based on OGO-6 retarding potential analyzer data," *J. Geophys. Res.* **78**, 7431, 1973.

Mendillo, M., G. S. Hawkins, and J. A. Klobuchar, "A large-scale hole in the ionosphere caused by the launch of Skylab," *Science*, **187**, 343, 1975a.

Mendillo, M., G. S. Hawkins, and J. A. Klobuchar, "A sudden vanishing of the ionospheric F Region due to the launch of Skylab," *J. Geophys. Res.* **80**, 217, 1975b.

Mendillo, M., and J. M. Forbes, "Artificially created holes in the ionosphere," *J. Geophys. Res.* **83**, 151, 1978.

Morse, F. A., B. C. Edgar, H. C. Koons, C. J. Rice, W. J. Heikkila, J. H. Hoffman, B. A. Tinsley, J. D. Winningham, A. B. Chistensen, R. R. Woodman, J. Pomalaza and N. R. Teixeira, "Equion, an equatorial ionospheric irregularity experiment," *J. Geophys. Res.* **82**, 578, 1977.

Oppenheimer, M., A. Dalgarno, F. P. Trebino, L. H. Brace, H. C. Brinton, and J. H. Hoffman, "Daytime chemistry of NO^+ from atmospheric explorer-C measurements," *J. Geophys. Res.* **82**, 191, 1977.

Oppenheimer, M., and L. Brace, "Recombination rate coefficient of NO^+ from thermosphere daytime chemistry," *Trans. Am. Geophys. Un.* **57**, 297, 1976.

Ossakow, S. L., and P. K. Chaturvedi, "Morphological studies of rising equatorial Spread F bubbles," *J. Geophys. Res.* **83**, 2085, 1978.

Ossakow, S. L., S. T. Zalesak, B. E. McDonald, and P. K. Chaturvedi, "Nonlinear equatorial Spread F: Dependence on altitude of the F peak and bottomside background electron density gradient scale length," *J. Geophys. Res.* **84**, 17, 1979.

Ossakow, S. L., S. T. Zalesak and B. E. McDonald, "Ionospheric modification: An initial report on artifically created equatorial spread F", *Geophys. Res. L.* **5**, 691, 1978.

Ossakow, S. L., "Research at NRL on theoretical and numerical simulation studies of ionospheric irregularities," NRL Memo Rept. 2907, Oct. 1974.

Ott, E., "Theory of Rayleigh-Taylor bubbles in the equatorial ionosphere," *J. Geophys. Res.* **83**, 2066, 1978.

Pongratz, M. B., G. M. Smith, C. D. Sutherland and J. Zinn, "Lagopedo — Two F-region ionospheric depletion experiments," in *Effect of the Ionosphere on Space and Terrestrial Systems*, edited by J. M. Goodman, p. 438, U. S. Government Printing Office (1978).

Scannapieco, A. J., and S. L. Ossakow, "Nonlinear equatorial Spread F," *Geophys. Res. Letts.* **3**, 451, 1976.

Sjolander, G. W., C. Y. Johnson, J. C. Holmes, and E. P. Szuszczewicz, "Ion composition measurements of a chemically modified ionosphere — An initial report," in *Effect of the Ionosphere on Space and Terrestrial Systems*, edited by J. M. Goodman, p. 442, U. S. Government Printing Office (1978).

Sjolander, G. W., and E. P. Szuszczewicz, "Chemically depleted F_2 ion composition : Measurements and theory," *J. Geophys. Res.* (1979, in press).

Sudan, R. N., J. Akinrimisi, and D. T. Farley, "Generation of small-scale irregularities in the equatorial electrojet," *J. Geophys. Res.* **78**, 240, 1973.

Szuszczewicz, E. P. and J. C . Holmes, "Surface contamination of active electrodes in plasmas: Distortion of conventional Langmuir probe measurements," *J. Appl. Phys.* **46**, 5134, 1975.

Szuszczewicz, E. P., "Ionospheric holes and equatorial spread F," NRL Memorandum Rpt. 3554 (July 1977).

Szuszczewicz, E. P., "Ionospheric holes and equatorial spread F: Chemistry and transport," *J. Geophys. Res.* **83**, 2365, 1978.

Torr, D. G, M. R. Torr, J. C. G. Walker, L. H. Brace, H. C. Brinton, W. B. Hanson, J. H. Hoffman, A. O. Nier and M. Oppenheimer, "Recombination of NO^+ in the ionosphere," *Geophys. Res. Letts.* **3**, 209, 1976.

Woodman, R. F. and C. La Hoz, "Radar observations of F-region equatorial irregularities," *J. Geophys. Res.* **81**, 5447, 1976.

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